A REGIONAL APPROACH TO HIGHWAY SOILS CONSIDERATIONS IN INDIANA

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BY

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JHRP

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Technical Paper

A REGIONAL APPROACH TO

HIGHWAY SOILS CONSIDERATIONS IN INDIANA

TO: J. F. McLaughlin, Director
Joint Highway Research Project

December 28, 1971

FROM: H. L. Michael, Associate Director
Joint Highway Research Project

File: 6-1

The attached Technical Paper "A Regional Approach to Highway Soils Considerations in Indiana" by Messrs. W. J. Sisiliano and C. W. Lovell, Jr. is forwarded to the Board for information. It will be presented to and published by the Highway Research Board. The paper will be presented at the 1972 Annual Meeting of the Board in Washington in January.

The paper is a summary of portions of the research report of the same title presented to the Board on an earlier date. The research was performed without Project support except for incidental costs of preparing reports and copies of this paper.

Respectfully submitted,

Harold L. Michael

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Associate Director

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Technical Paper

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A REGIONAL APPROACH TO HIGHWAY SOILS CONSIDERATIONS IN INDIANA

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A paper submitted to the Highway Research Board for presentation at the 51st Annual Meeting, Washington, D. C., January, 1972.

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INFORMATIVE ABSTRACT

A REGIONAL APPROACH TO HIGHWAY SOILS CONSIDERATIONS IN INDIANA

by

William J. Sisiliano and C. W. Lovell, Jr.

It is hypothesized that a Regional or Physiographic Subdivision Approach can be effectively used in preliminary studies and investigations generally to predict the environment and to formulate the major soils problems to be considered in the design of a modern highway facility. This is intuitively obvious to practicing soils engineers, although they may not think of it in exactly these terms. Each practicing soils engineer tends to develop his own personal filing system of engineering experiences, usually based on geographic location, rather than physiographic unit.

Those factors which appear to be most significant are the geologic origin and complexity of the soil parent materials, the topography, and the general texture of the soils. If the influence of these factors can be quantified within a physiographic region, the anticipated soils problems and their general magnitudes may be predicted for a project in that region.

Both generalized and specific quantification of significant factors influencing a Regional Approach to highway soils considerations have been proposed. Available data from physiography, geology, pedology,

remote sensing and engineering soils mapping were used in the general approach. Data were compiled from completed Indiana State Highway Commission Projects and Roadway Soil Surveys performed by consultants, and statistical methods were applied to some of these data in the specific approach. A Table entitled "Ratings of Highway Soils Considerations for Landforms within Physiographic Regions of Indiana" probably contains the most useful information resulting from this study, particularly for soils engineers inexperienced in this geographic location.

To be of practical consequence, the findings and conclusions of this study must be interpreted in terms of the present standards, policies and procedures concerning Roadway Soil Surveys used by the Indiana State Highway Commission. Therefore, the general relationships between the State of Indiana's methods for performing Roadway Soil Surveys and a Regional Approach to highway soils considerations in Indiana are being investigated.

It is concluded that the Physiographic Subdivision Approach is capable of contributing significantly and economically in the preliminary stages of planning, route location and design of modern highway facilities in the State of Indiana. To optimize the approach, a further subdivision of the Physiographic Units (shown on Figure 1) is required. The landforms or Engineering Soil Parent Material Areas shown in Reference (3) seem to provide areas of sufficient homogeneity.

Within such areas, the classes and severity ratings of highway soils problems can probably be generalized with confidence. This was accomplished for the Calumet Lacustrine Plain, a subsection of the

Northern Lake and Moraine Region. It is felt that the same procedure can be applied to the other physiographic units to provide similar information of practical value to the Indiana State Highway Commission.

INTRODUCTION

Among the factors to be considered in the planning, location, design and construction of modern highway facilities are the soil and rock conditions within the corridor of the proposed route. These conditions are inherently complex and will need to be studied in detail before certain design and construction decisions are reached. However, there is considerable logic in deriving a generalized description of them prior to assessing details. This can be accomplished by examination of the factors of origin, parent material, topographic expression and climatic environment. If the engineer has job experience where these general factors were similar, even though geographically removed from the route under study, he has a valid basis for the transfer of past experience. In other words, he can anticipate the likely challenges of the new project. A recognition of these interrelations and a concise recording of them would allow even an inexperienced engineer to exercise valuable insight. All of this occurs at the <u>preliminary stage</u> of investigation and is intended to enhance the interpretation of detailed physical studies, as opposed to displacing them.

As suggested above, the descriptors which appear most significant in a generalized assessment of route conditions are the geologic origin and complexity of the parent materials, the topographic expression, and the general texture of the soil, particularly clay content. The topographic expression is conveniently characterized by the branch of geology known as physiography or regional geomorphology, which defines units of unique landform combinations based upon factors of structure, process and stage. Therein lies the basis for the Regional or Physiographic Subdivision Approach. The physiographic units of Indiana adopted for this study are those defined by Malott (11)[1] as shown in Figure 1. A further subdivision to the landform or Engineering Soil Parent Material Area level is needed to characterize the geologic origin and complexity of the soil parent materials, and to afford a measure of the soil distribution throughout the physiographic region. References (1), (3) and (23) were used for this purpose. The general texture of the soils is described by various soil index properties, which must be determined by physical tests.

PURPOSE

The objective of this paper is to show that a Regional or Physiographic Subdivision Approach may be effectively used in preliminary studies and investigations to predict the general soil and rock environment and to provide significant insight into the kinds of problems to be anticipated in the design and construction of a modern highway facility. A future goal is to indicate how the

1. Underlined numbers in parenthesis refer to entries in the List of References.

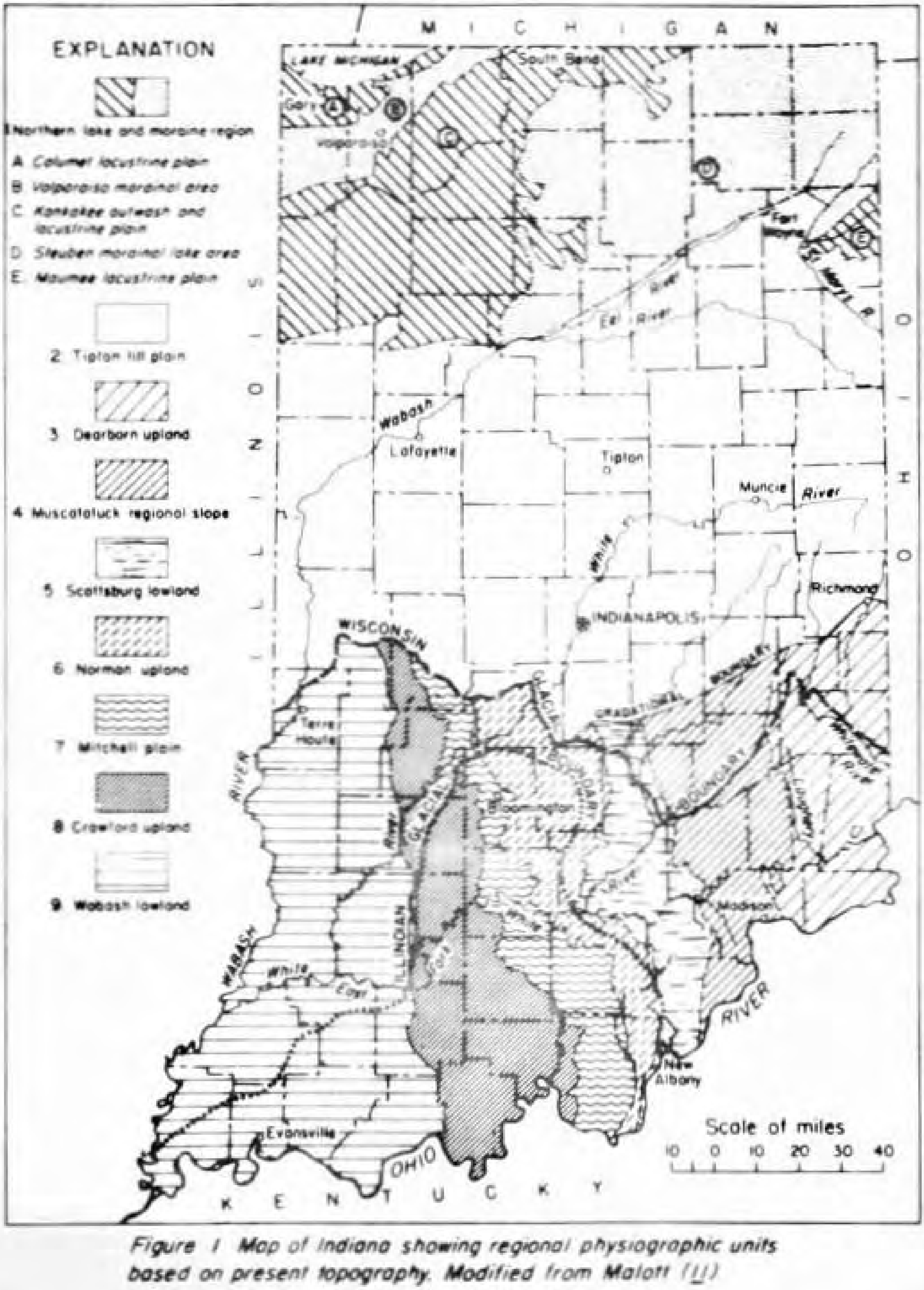


Figure 1 Map of Indiana showing regional physiographic units based on present topography. Modified from Malott (11)

approach can be integrated into the present Indiana State Highway Commission's standards, policies and procedures for performance of Roadway Soil Surveys. In addition to the generalizations possible at the physiographic unit level, variability of soil characteristics was assessed for significant landforms within one unit. The purpose was to ascertain the variability of soil conditions within a landform and to frame correlative equations for selected soil characteristics for the landform unit.

That class of soils considerations peculiarly related to pavement design and construction have been omitted from this study due to their specialized nature and the complex and highly relevant soil-structure interaction effects.

GENERAL BACKGROUND

Physiography

Elements of Physiography

As stated by Witczak (24), "In the simple view, physiography permits subdivision into areas of contrasting or distinctive topographic expression. Such division is effected by an examination of three geomorphic control factors, viz., structure, process, and stage (20).

"Structure is a comprehensive term defined in (20) as '... all those ways in which earth materials out of which landforms are carved differ from one another in their physical and chemical attributes'. In a sense, structure expresses the type and arrangement of parent materials.

"*Process* describes the factors of origination and modification primarily responsible for the landscape. Processes may act constructively or destructively and may originate above the earth surface (e.g., wind, water, ice) or below it (viz., diatrophism or vulcanism). Thus process may be interpreted as *origin*.

"The operation of process upon structure in the development of the landscape involves various evolutionary phases or stages. Thus, this term conveys the notion of time of aging under ambient climate conditions, or the factor of *age*.

"In summation, the topographic expression is a function of the geologic parent material, the geomorphic processes acting, and the time and climate of action. These factors are highly relevant to landscape classification for engineering purposes, although they are probably not sufficiently quantified."

A physiographic unit is characterized by a mode of topographic expression which is different from those of adjacent units. However, certain variations from the modal pattern occur and these variants are included as a matter of necessity. It is therefore logical that the physiographic subdivision becomes more "homogeneous" as the division becomes more limited in size. Malott (*11*) recognized this about 50 years ago when he outlined the basic physiographic subdivisions of Indiana, and described them in considerable detail.

Physiography of Indiana

The State of Indiana lies within the Central Plains physiographic province of North America as determined by Atwood (*2*). In the classical scheme of Fenneman (6), the maximum extent of glaciation is the boundary between the Till Plains Sections of the Central Lowland Province and the Highland Rim and Bluegrass Section of the Interior Low Plateau Province to the south. Approximately the northern fourth of the state lies within the Eastern Lake Section of the Central Lowland Province.

Wayne (22) states that Indiana can generally be divided into three broad physiographic divisions trending in an east-west direction across the State. The central division, comprising about one-third of the state area, is a depositional plain of low relief, underlain largely by thick glacial till and modified only slightly by postglacial stream erosion. It is called either the Central Drift Plain or the Tipton Till Plain.

The northern division is called the Northern Lake and Moraine Region and comprises slightly less than one-fourth of the state area. It is divided into five subdivisions, as shown on Figure 1. The northern division is characterized by greater relief than the central division, being very hilly in some areas; but even in these areas, the uplands are interrupted by lowlands and plains of little relief. Landforms in this division are mostly of glacial origin. A large variety of depositional forms is present, including end moraines, outwash plains, kames, lake plains, valley trains and kettle holes, as well as many related post glacial features such as lakes, sand dunes, and peat bogs.

The roughest topography in Indiana is formed in the southern division, which is divided into seven subdivisions (see Figure 1).

Landforms in this division are primarily the result of normal degradational processes, such as weathering, stream erosion, and mass movement. The middle part of the southern division was not glaciated and the topography strongly reflects the nature of the parent bedrocks. The units on either side were glaciated, but the influences of glaciation were minor and the physiography is largely bedrock controlled. An exception in part is the Wabash Lowland where many lacustrine areas, valley trains and outwash plains have developed as a result of glacial activity.

Geology

Glacial

Most of the surface of Indiana has been glaciated to varying degrees by the various continental glacial advances. The south central portion of the State was not affected by the sculptoring effects of the ice sheet, thus the topography, drainage and soils have been formed through the weathering of the Paleozoic sediments.

Reference (23) shows the various glacial formations and landforms throughout the State. The lacustrine deposits resulting from Illinoian and Wisconsin Glacial Stages are mapped in some detail by Thornbury (19). A map showing the thickness of drift north of the Wisconsin glacial boundary has been prepared by Wayne (22).

Bedrock

An excellent and thorough account of the bedrock geology and stratigraphy is presented in the Handbook of Indiana Geology by Cummings (5). The various bedrock formations along with their areal extent and several typical bedrock cross sections are shown on Reference (14). Bedrock physiographic units as shown in (22) were originally developed by Malott (11). The bedrock physiographic units in southern Indiana generally have north-south boundaries which conform to the physiographic subdivisions previously discussed. It can be clearly seen, by comparison, that the east-west boundaries for the bedrock units extend much further north, reflecting the sub-surface geology. It can also be seen that the northern bedrock physiographic units have lateral limits very much modified from the previously discussed physiographic units.

The dominant lithologies of the various bedrock physiographic units can be found in Wayne (22). The formations and geologic age of these consolidated deposits are detailed in Cummings (5) and in Reference (12).

Pedology

References (3, 4, 8, 17, 21 and 25) are on the pedologic approach to classification and distribution of Indiana soils. Reference (1) maps the pedologic soil associations and provides valuable soil series descriptions.

The Soil Conservation Service (SCS) has prepared four tabulations of soil indices and interpretative ratings of these soils for various related fields of interest to us and practical applications. The SCS Table No. 1, is entitled "Brief Description of Soils of Indiana and their Estimated Physical and Chemical Properties"; the second SCS table, is entitled "Interpretation of the Soils in Indiana for Rural and Urban Development"; SCS Table No. 3, is entitled "Interpretations of Engineering Properties of Major Soils in Indiana, Non-Agricultural (Urban)"; and SCS Table No. 4, is entitled "Interpretation of Engineering Properties of Major Soils in Indiana for Agriculture". In addition, modern SCS county soil surveys contain simple engineering soil data.

Remote Sensing

Aerial photographic interpretation has been the dominant tool in the preparation of county engineering soils maps. These maps are available for many counties in Indiana, and have been summarized by McKittrick (13).

Several other reports were very useful in this research, viz., (3, 7, 13, and 15). Other excellent reports have been prepared as a part of the Joint Highway Research Project for air-photo interpretation of some major parent material regions in Indiana. These have also been summarized by McKittrick (13).

Engineering Soils

The mapping of soils and rocks depends most strongly in its form upon, (a) the scale, and (b) the perspective and objective of the mapper. All maps are generalizations, and the smaller the scale the greater the degree of generalization. All mapping needs to be based upon descriptors which are relatively simple and easy to determine. The descriptions chosen by the engineer are those which are both convenient and highly useful for framing the general nature of design and construction problems. Such maps provide valuable insight for

<u>preliminary studies</u> such as route location and setting up a boring program for any given project. On occasion they may substitute for field studies, e.g., where the latter do not appear economically justifiable.

An outstanding effort to map and describe the soils of Indiana, drawing heavily on available pedologic data, was made by Belcher, Gregg and Woods in their Bulletin 87 entitled, "The Formation, Distribution and Engineering Characteristics of Soils" (<u>3</u>). This work led to a map of "Engineering Soil Parent Materials of Indiana".

As previously mentioned, certain county engineering soils maps have been prepared through interpretation of black and white aerial photography, usually supplemented by limited boring, sampling and testing. As might be expected the county maps give more detail due to the larger scale.

GENERALIZED QUANTIFICATION OF SIGNIFICANT FACTORS INFLUENCING A REGIONAL APPROACH

Several original procedures were used generally to quantify the distribution of soil parent material areas or landforms within each physiographic region. Other related factors were also investigated.

<u>Methods of Generalized Quantification</u>

A first and obvious step in generalized quantification was to compare the State physiographic regions with other state maps depicting topography, geology, pedologic units, engineering soil parent material areas, and thickness of drift. All of these maps were readily available. The comparisons are described in some detail below.

Topography

The topographic map by Logan (10) has a 100-foot contour interval and a scale of approximately 1:500,000 or about 1 1/4 inch to 10 miles. It is the largest scale state topographic map known to the writers. Since topography is considered to be a major factor, it was analyzed for each physiographic subdivision in a number of ways, e.g., the frequency distribution of elevation was defined. Areas within defined elevation intervals were planimetered, and curves of Terrain Elevation Interval vs. Percent Area Physiographic Region were prepared. The curve obtained for the Calumet Lacustrine Plain is included on Figure 2.

Curves obtained for this phase of the study were typically one of three types.

<u>Type 1</u>. A high peak or mean value for Percent Area Physiographic Region and a narrow range for Terrain Elevation Interval characterize this group. Slight local relief and minor topographic expression are generally implied, i.e., almost level to gently undulating terrain.

<u>Type 2</u>. Such curves have a moderate to high peak or mean value for Percent Area Physiographic Region and a moderate to wide range for Terrain Elevation Interval. Moderate variations in local relief and moderate topographic expression, viz., gently undulating to rolling terrain are indicated.

<u>Type 3</u>. A small to moderate peak or mean value for Percent Area Physiographic Region and a wide range for Terrain Elevation Interval

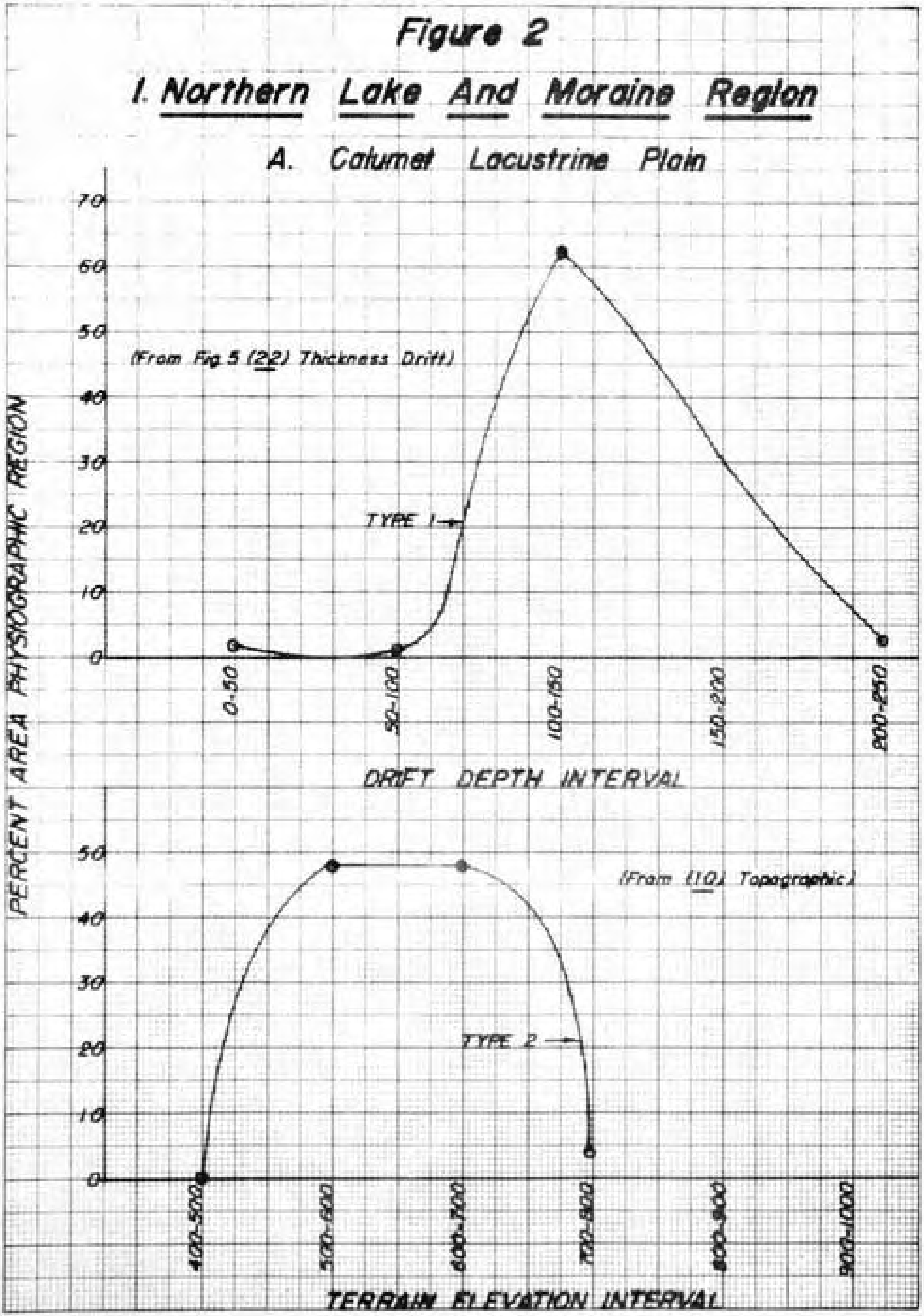


Figure 2
I. Northern Lake And Moraine Region
A. Calumet Lacustrine Plain
PERCENT AREA PHYSIOGRAPHIC REGION
(From Fig. 5 (22) Thickness Drift)
TYPE 1
0-50
50-100
100-150
150-200
200-250
DRIFT DEPTH INTERVAL
(From (10) Topographic)
TYPE 2
400-500
500-600
600-700
700-800
800-900
900-1000
TERRAIN ELEVATION INTERVAL

characterizes these curves. Large variations in local relief and major topographic expression are implied, i.e., rolling to rough terrain.

Thickness of Drift

North of Wisconsin Glacial Boundary

The thickness of drift map was prepared by Wayne (22). The scale of this map is 1:500,000, or approximately 1 1/4 inch to 10 miles, and a contour interval of 50 feet is used. The thickness of unconsolidated deposits in Indiana south of the Wisconsin glacial boundary has not been mapped to the present time. Since depth to bedrock or thickness of drift is an important factor for many engineering projects, a frequency distribution of depth was developed for each physiographic region. Areas between defined depth intervals were planimetered and distribution curves drawn. These curves show the Drift Depth Interval vs. Percent Area Physiographic Region. The curve obtained for the Calumet Lacustrine Plain is also included on Figure 2.

Curves obtained for this phase of the study were typically one of two types.

Type 1. These curves showed an approximate normal distribution, with low percentages for extreme values and a peak at about the distribution mean. Such curves generally indicate the bedrock is well covered and will be encountered infrequently in an average project.

Type 2. These distributions are skewed to the left, i.e., the curve peaks near the left extreme instead of near the mean value. Since the left extreme is the Drift Depth Interval of 0 to 50 ft., bedrock may be encountered more than occasionally on an average project. The probability of encountering bedrock on a project is dependent upon the actual percentage for the 0 to 50 ft. interval and to a lesser extent on the percentage for the 50 to 100 interval.

Engineering Soil Parent Material Areas

Such a map is available as a 1950 revision of the 1943 map of Bulletin No. 87 (3). The scale is approximately 3/4 inch equals 10 miles. The physiographic subdivisions were outlined on this map, and the area of each engineering soil parent material occurring within a physiographic region was planimetered. This information has been plotted as bar graphs of Soil Type (Parent Material) vs. Percent Area Physiographic Region. The information is shown on Figure 3 for the Calumet Lacustrine Plain.

Glacial Geology

The mapping is a part of the Atlas of Mineral Resources of Indiana (Map No. 10) and was prepared by Wayne (23) in 1958. The scale is 1:1,000,000 or approximately 5/8 inch equals 10 miles. It shows the predominant soil areas of glacial origin for the glaciated part of the State. Again frequency distribution bar graphs were plotted, and the information for the Calumet Lacustrine Plain is also shown on Figure 3.

Pedology

A "Map of Indiana Soils" (1) shows Soil Regions (parent material areas) and associations of soil series within the Regions. In many

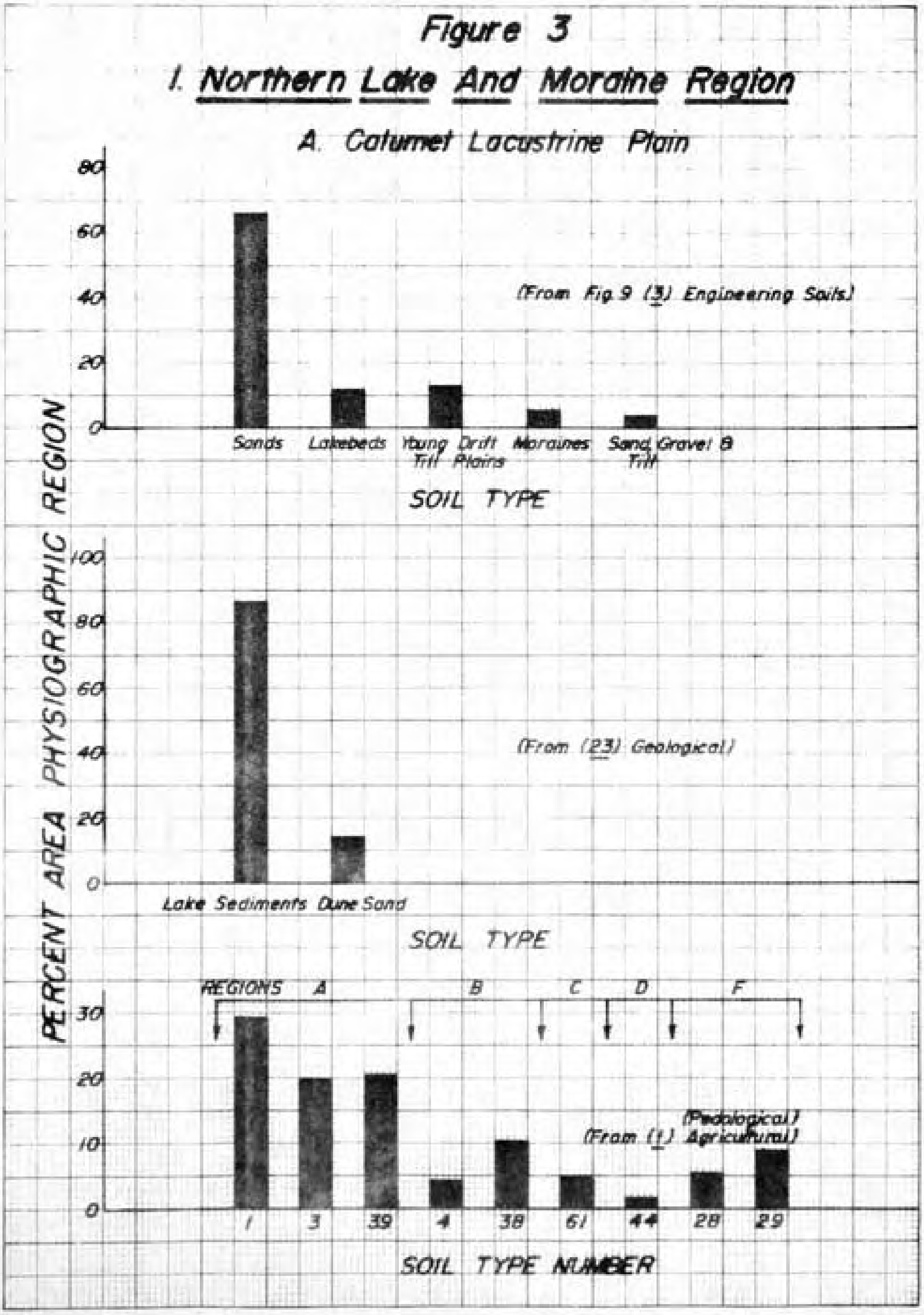


Figure 3
I. Northern Lake And Moraine Region
A. Calumet Lacustrine Plain
PERCENT AREA PHYSIOGRAPHIC REGION
(From Fig. 9 (3) Engineering Soils)
Sands
Lakebeds
Young Drift Till Plains
Moraines
Sand, Gravel & Till
SOIL TYPE
(From (23) Geological)
Lake Sediments
Dune Sand
SOIL TYPE
REGIONS A B C D F
(Pedological)
(From (1) Agricultural)
1 3 39 4 38 61 44 28 29
SOIL TYPE NUMBER

areas of the State, the boundaries for the Soil Regions correspond to the boundaries of (3), which emphasizes the probable utility of such mapping for engineering purposes. The four Tables prepared by the Soil Conservation Service are helpful in interpreting the pedologic mapping for engineering applications.

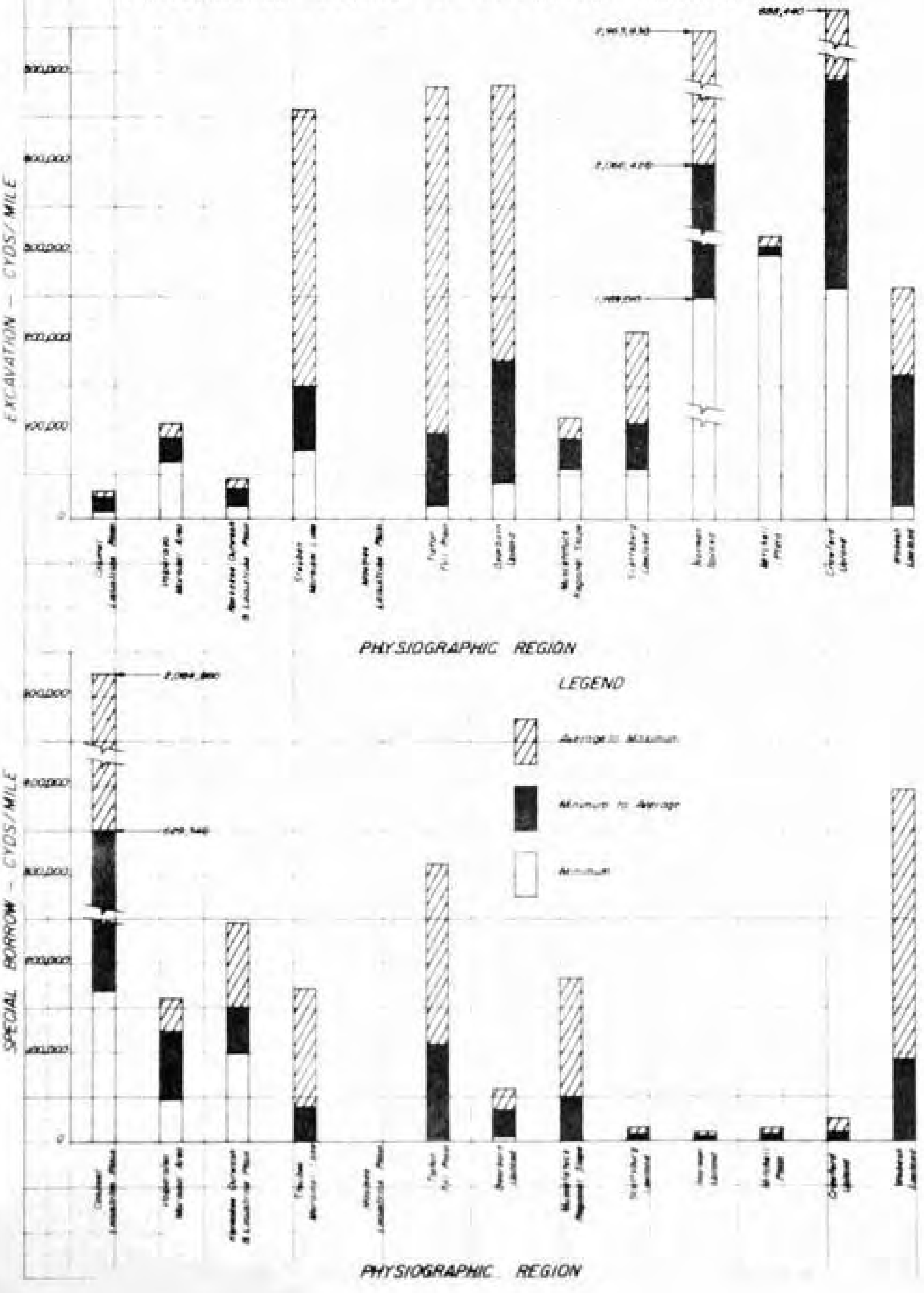
The physiographic subdivisions were transferred to the State Pedologic map and the area of each series association within a physiographic region was planimetered. This information has been shown in the form of bar graphs of Series Association Number vs. Percent Area Physiographic Region, on Figure 3 for the Calumet Lacustrine Plain.

Earthwork Quantities by Physiographic Regions

A further generalized quantification involved tabulating the earthwork quantities for Indiana highway projects within each physiographic region for Interstate, Primary and Secondary roads. Only those relatively recent projects for which data were readily available were used. A portion of the data for the Interstate projects was plotted as bar graphs of Physiographic Regions vs. Excavation or Special Borrow, Figure 4. These data serve as indicators of topographic variation or roughness of terrain. However, they are also a function of the standard requirements for alignment, grade and geometry of roadway cross-section for the various classes of projects. An earthwork Factor was defined as $(E, \%) = \frac{\text{Special Borrow Per Mile}}{\text{Special Borrow Per Mile} + \text{Excavation Per Mile}}$ X 100. The Earthwork Factor for the Calumet Lacustrine Plain was 96% for Interstate highways.

FIGURE 4

EARTHWORK QUANTITIES BY PHYSIOGRAPHIC REGIONS FOR INTERSTATE PROJECTS



Aggregate Availability and Use Data

Rock quarry and sand and gravel pit data were also prepared for each physiographic region. The data may be used as indicators of: (a) the occurrence of valley train and outwash plain sediments, and (b) the occurrence of carbonate bedrock at relatively shallow depths.

Slope Instability

A survey of highway slope failures was conducted and analyzed with respect to the physiographic subdivisions; see Table 1. The "normalization" of failures with respect to subdivision area is a convenient but approximate technique. The Table does indicate however, that the parent materials and other environmental factors are more conducive to slope instability in some subdivisions than in others.

Other Aspects of the Generalized Quantification

At this point let us consider the relative uniformity that is exhibited by the various physiographic subdivisions with respect to factors considered for generalization.

The relative percentages of significant soil parent material areas in the physiographic regions can be viewed as a first measure of uniformity. The logic of this premise can be illustrated by the following example. Refer to the two upper bar graphs of Figure 3, and consider the circumstance of a small number of significant soil parent material areas or landforms in a physiographic region. "Significant" areas are those comprising more than five percent (5%) of the total physiographic region. Where the relative percentages

TABLE 1 MEASURES OF REGIONAL UNIFORMITY

Physiographic Region	Summary of Slope Failures per Physiographic Region		Ratings for 1st Degree of Uniform. for Soil Parent Mat. Areas Within Ea. Physiographic Region	Summary of Terrain Quantification Factors For Physiographic Regions	
	Number of Failures	"Normalization" Sq. Mi. per Failure	Rating	Coefficient of Variation, V (%)	Topographic Coefficient, T (%)
1. Northern Lake and Moraine Region					
A. Calumet Lacustrine Plain	0	-	II	22.5	9.6
B. Valparaiso Morainal Area	1	619	I - II	17.4	7.8
C. Kankakee Outwash & Lacustrine Plain	0	-	IV	23.6	10.6
D. Steuben Morainal Lake Area	2	1,842	III	23.8	8.3
E. Maumee Lacustrine Plain	0	-	I	0	100.0
2. Tipton Till Plain	1	13,435	II - III	22.8	3.7
3. Dearborn Upland	16	114	III - IV	29.8	2.4
4. Muscatatuck Regional Slope	0	-	III	25.8	3.1
5. Scottsburg Lowland	4	373	IV	25.3	5.0
6. Norman Upland	2	617	III - IV	26.5	2.9
7. Mitchell Plain	2	647	III	19.3	5.2
8. Crawford Upland	10	243	II - III	27.2	3.1
9. Wabash Lowland	3	1,646	IV	26.0	7.2
TOTAL	41				

Definition:

I-Very Uniform (1 to 2 Sign. L.F.)
II-Uniform (2 to 3 Sign. L.F.)
III-Slightly Uniform (3 to 4 Sign. L.F.)
IV-Complex (5 or more Significant Landforms)

are high, only a few soil parent material areas are present and these are presumedly repeating in a common or dominant pattern. This situation is viewed as a relatively uniform one. Such a first approximation of uniformity is shown in Table 1, where four general ratings have been established.

A second degree of measure of uniformity within a physiographic region involves the soil series associations encountered within the soil parent material areas or landforms. Consider the lower bar graph of Figure 3. A small number of significant associations within a soil parent material area is interpreted to mean a high degree of uniformity.

SPECIFIC QUANTIFICATION OF SIGNIFICANT FACTORS INFLUENCING A REGIONAL APPROACH

As stated previously, the significant factors influencing a regional approach to highway soils considerations are the geologic origin and complexity of parent materials (or landforms), topography, and the texture of the parent materials (particularly the percentage of the clay fraction). This section on "Specific Quantification" presents an approach for handling these factors in some detail.

Distribution of Interstate Mileage Within Physiographic Regions, Landforms and Soil Types

The Interstate highway mileage within each landform or numbered soil area was determined as a percentage of the total Interstate mileage within the physiographic region. These data tend to answer the question, "What landforms, soil types or soil type numbers do our existing or designed highways traverse?" With this information, one can speculate as to the nature of the soils considerations and whether their magnitudes could be lessened by route relocation to traverse more desirable landforms. Economics is the criterion, and both initial cost and maintenance costs, should be included. The information is included in detail in the original study (16).

Roadway Soil Survey Data for Cuts by Physiographic Region

One can make some very effective inferences about the nature of the terrain, the adequacy of standard design backslopes and whether rock excavation will be required on a given project, if he has a summary of the cut information for other projects in the same region. Therefore, a detailed study was made of the proposed cuts in the consultants Roadway Soil Surveys. Numerous cut statistics have been developed and included in (16). The inferences are: the lesser number and shallower depth of cuts indicate more level terrain; the shallower average depth of cuts implies more stable backslopes, and the frequency of rock cuts is uniquely related to the physiographic region. The bedrock information is especially useful south of the Wisconsin Glacial Boundary, where thickness-of-drift maps are not applicable.

Specific Terrain Quantification Factors for Physiographic Regions

Several terrain descriptors were determined for the Terrain Elevation Interval Curves which were prepared. These are the "Coefficient of Variation, V(%)", a statistical tool, and the Topographic Coefficient, T(%), defined for the purpose of this study. These values were calculated for the curves obtained for each physiographic region and are presented in Table 1. The significance and usefulness of these results have been shown in Table 2, entitled "Conclusions about Terrain Quantification Factors for Physiographic Regions". The table shows that limits set for these values can be used to predict the general soil origin.

Typical Profiles and Physical Properties of Soils for Significant Landforms Within Physiographic Regions

To demonstrate some degree of uniformity or frequency of occurrence for the soil types encountered within each significant landform within a physiographic region, "Typical Profiles" were developed for the Calumet Lacustrine Plain. The data for the physical properties of the soils comprising each significant landform were subjected to statistical methods and procedures in an attempt to characterize each significant layer or stratum within each typical profile. In addition to a typical profile, some pertinent relationships and the regression equations have been developed.

Typical Profiles

Typical profiles were prepared for each of the three significant landforms or soil parent material areas as defined by the map "Engineering Soil Parent Material Areas in Indiana", in the Calumet Lacustrine Plain. "Significant" has been defined as more than 5 percent of the physiographic region area. Thus, typical profiles were prepared for the dune sand, lakebed, and ground moraine (Wisconsin) areas, which constitute about 66, 12 and 13 percent, respectively, of the approximate 279 square miles total.

TABLE 2

CONCLUSIONS ABOUT TERRAIN QUANTIFICATION FACTORS FOR PHYSIOGRAPHIC REGIONS

Coefficient of Variation, V	Topography	Physiographic Regions	Origin
$(V < 5)$	Level to gently undulating	1E	Lacustrine
$(5 \le V \le 25)$	Gently undulating to undulating	1A;1B;1C;1D;2;7	Glacial
$(V > 25)$	Undulating to rolling	3;4;5;6;8;9	Residual

Where: $V = \frac{S(100)}{x}$ = Coefficient of Variation

$\left.\begin{array}{l} S = \text{standard deviation} \\ \bar{X} = \text{mean value} \end{array}\right\}$ from Terrain Elevation Interval Curves

Topographic Coefficient, T	Topography	Physiographic Regions	Origin
$(T > 25)$	Level to gently undulating	1E	Lacustrine
$(25 \ge T \ge 5)$	Gently undulating to undulating	1A;1B;1C;1D;5;7;9	Glacial
$(T < 5)$	Undulating to rolling	2;3;4;6;8	Residual

Where: $T = \frac{\text{Max. ordinate}}{\text{No. contour interval}}$ = Topographic Coefficient

from Terrain Elevation Interval Curves

One needs to make use of all conveniently available sources to avoid erroneous conclusions. For example, consider the large area shown as dune sand on the map of "Engineering Soil Parent Material Areas in Indiana". If we consider this information, along with that of "A Map of Indiana Soils" (Pedologic), the impression is gained that sand is the engineering material. (Pockets, layers and lenses of peat, marl and other organic soils are expected in the depressions between the sand dunes.) However, the entire soil parent material area shown as dune sand is underlain by a deep deposit of lacustrine sediments from Glacial Lake Chicago, consisting of compressible fine grained soils. This fact would be evident from the map, "Glacial Geology of Indiana". The consolidation of these underlying deposits due to superimposed loading might well control the design of many facilities.

An important part of the Typical Profile is the Statistical Soil Classification, which is based on average values for the pertinent physical characteristics used in the Textural and in the AASHO Classification Systems. These values were obtained from Roadway Soil Surveys performed for the Indiana State Highway Commission by consultants. Three different methods were used in determining the statistical soil classification.

Physical Properties

Physical properties of the soils in each significant landform were subjected to statistical methods and procedures in an attempt to characterize each significant layer or stratum within each

Typical Profile. Since "economy" is a major factor in the performance of any roadway soil survey, sufficient data were not always available. In areas where it was intuitively obvious that the proposed conditions would pose no challenge to the existing foundation soils, detailed information was not requested or supplied. This was the case for several of the strata involved in the Typical Profiles developed for this study.

The data compiled and the relationships determined are included in Table 3 and Figures 5, 6, 7 and 8 for the "Dune Sand" landform of the Calumet Lacustrine Plain. Development of similar information for landforms in other physiographic regions would be most useful, but would be a major undertaking. All such summaries should be continually updated as more information becomes available.

Ratings of Highway Soils Considerations for Landforms Within Physiographic Regions

Ratings of highway soil considerations for landforms within physiographic regions in Indiana are presented in Table 4 for the Calumet Lacustrine Plain. The writers consider that information of this type is potentially quite valuable for practicing soils engineers, inexperienced in this geographical location. The usefulness of these data (shown for the entire state in (16)) could be expanded, if other practicing soils engineers (experienced in this locale) were to offer constructive criticisms, and if their thoughts and experiences were to be reflected in a modified presentation. These ratings are primarily useful in the "Preliminary Studies" phase of highway

TABLE 3

1. NORTHERN LAKE AND MORAINE REGION

A. CALUMET LACUSTRINE PLAIN

TYPICAL PROFILE NO. 1

LANDFORM: DUNE SAND

Data for Statistical Soil Classification

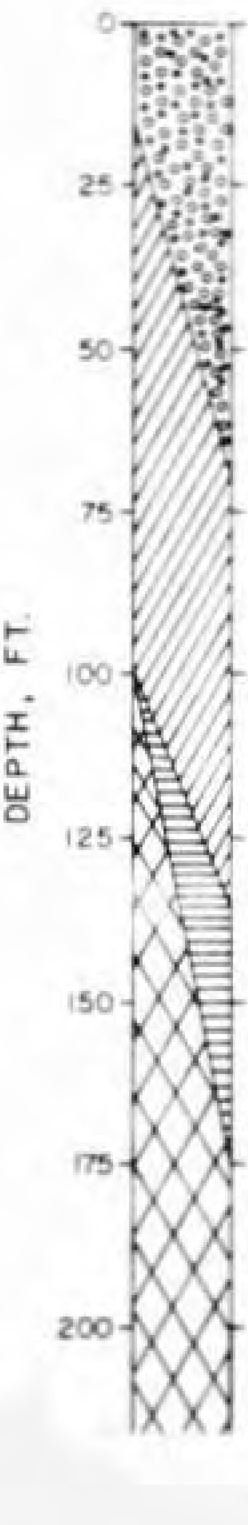
	DUNE SAND --STRATUM A								LAKEBED - STRATUM B						
	% Passing No. 40 Sieve	% Passing No. 200 Sieve	% Sand	% Silt	% Clay	Liquid Limit	Plasticity Index	Classification Textural AASHO	% Passing No. 200 Sieve	% Sand	% Silt	% Clay	Liquid Limit	Plasticity Index	Classification Textural AASHO
Average Value															
(Method 1) $\bar{X}_1$	85.7	5.9	94.1	[illegible]	1.9	N.P.	N.P.	Sand A-3(0)	87.6	12.4	58.6	29.0	28.4	12.5	Silty Clay Loam A-6(9)
(Method 2) $\bar{X}_2$	91.1	3.5	96.5	[illegible]	1.1	N.P.	N.P.	Sand A-3(0)	87.1	12.9	54.7	32.4	28.4	12.5	Silty Clay A-6(9)
(Method 3) $\bar{X}_3$	91.5	3.2	96.8	[illegible]	0.6	N.P.	N.P.	Sand A-3(0)	87.8	12.2	55.0	32.8	28.4	12.5	Silty Clay A-6(9)
Standard Deviation															
(Method 1) S_1	19.3	6.3	6.3	4.5	3.4	N.P.	N.P.		11.9	11.9	11.8	14.3	4.4	4.1	
(Method 2) S_2	14.7	5.0	5.0	3.4	2.6	N.P.	N.P.		12.4	12.4	11.6	14.3	4.2	4.0	
(Method 3) S_3	14.1	4.6	4.6	3.3	2.2	N.P.	N.P.		11.8	11.8	10.3	12.9	4.0	3.7	
Maximum Value, Max X_i	100	20	100	19	13	N.P.	N.P.		100	34	80	55	38	21	
Minimum Value, Min X_i	1	0	80	0	0	N.P.	N.P.		66	0	42	6	21	7	
Range R	99	20	20	19	13	N.P.	N.P.		34	34	38	49	17	14	

FIGURE 5

I. NORTHERN LAKE AND MORAINE REGION

A. CALUMET LACUSTRINE PLAIN

TYPICAL PROFILE NO. I LANDFORM: DUNE SAND



GROUND SURFACE ELEVATION AVE 600 (MAX 630, MIN 580)

STRATUM A
ORIGIN: DUNE SAND
STATISTICAL SOIL CLASSIFICATION:
TEXTURAL: SAND AASHO: A-3(0)
COMMENTS: FREQUENTLY DEPOSITS, POCKETS, LAYERS OR LENSES OF PEAT OR PEAT AND MARL OR OTHER ORGANIC SOILS OCCUR.

STRATUM B
ORIGIN: LAKEBED (GLACIAL LAKE CHICAGO)
STATISTICAL SOIL CLASSIFICATION:
TEXTURAL: SILTY CLAY AASHO: A-6(9)
COMMENTS: OCCASIONALLY WITH POCKETS, LAYERS OR LENSES OF SILTY LOAM.

STRATUM C
ORIGIN: GLACIAL DRIFT
SOIL DESCRIPTION: HARDPAN (VERY DENSE MIXTURE OF SAND AND GRAVEL IN A SILT AND CLAY MATRIX)

STRATUM D
ORIGIN: SILURIAN AND MIDDLE DEVONIAN SYSTEMS
BEDROCK DESCRIPTION: LIMESTONE, DOLOMITE, SHALE AND SANDSTONE

FIGURE 6

I NORTHERN LAKE AND MORAINE REGION

A CALUMET LACUSTRINE PLAIN

TYPICAL PROFILE NO
LANDFORM - DUNE SAND

STRATUM A
STATISTICAL SOIL CLASSIFICATION -
TEXTURAL SAND
AASHO: A-3(0)

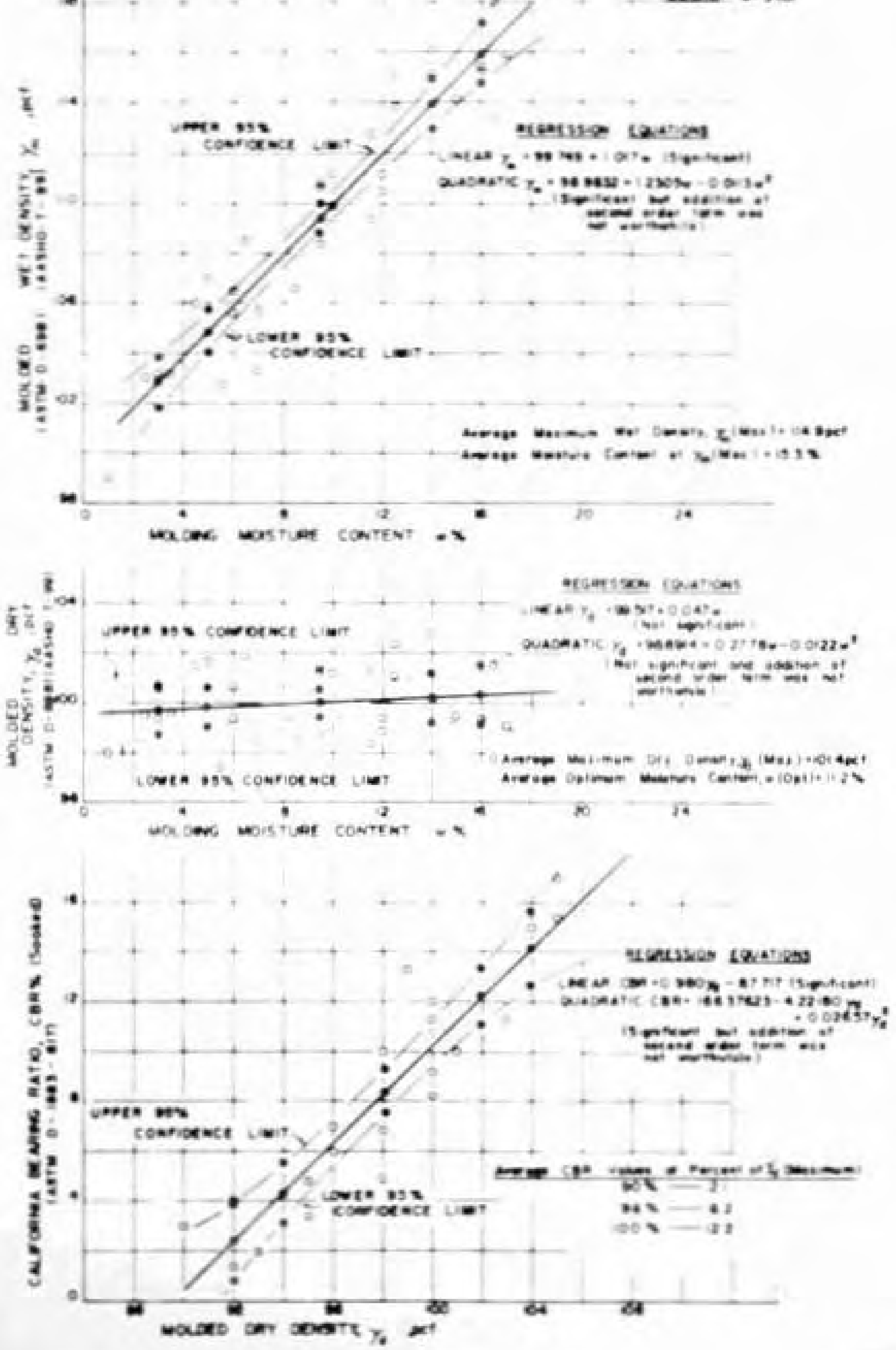


FIGURE 7

I. NORTHERN LAKE AND MORAINE REGION

A. CALUMET LACUSTRINE PLAIN

TYPICAL PROFILE NO. I

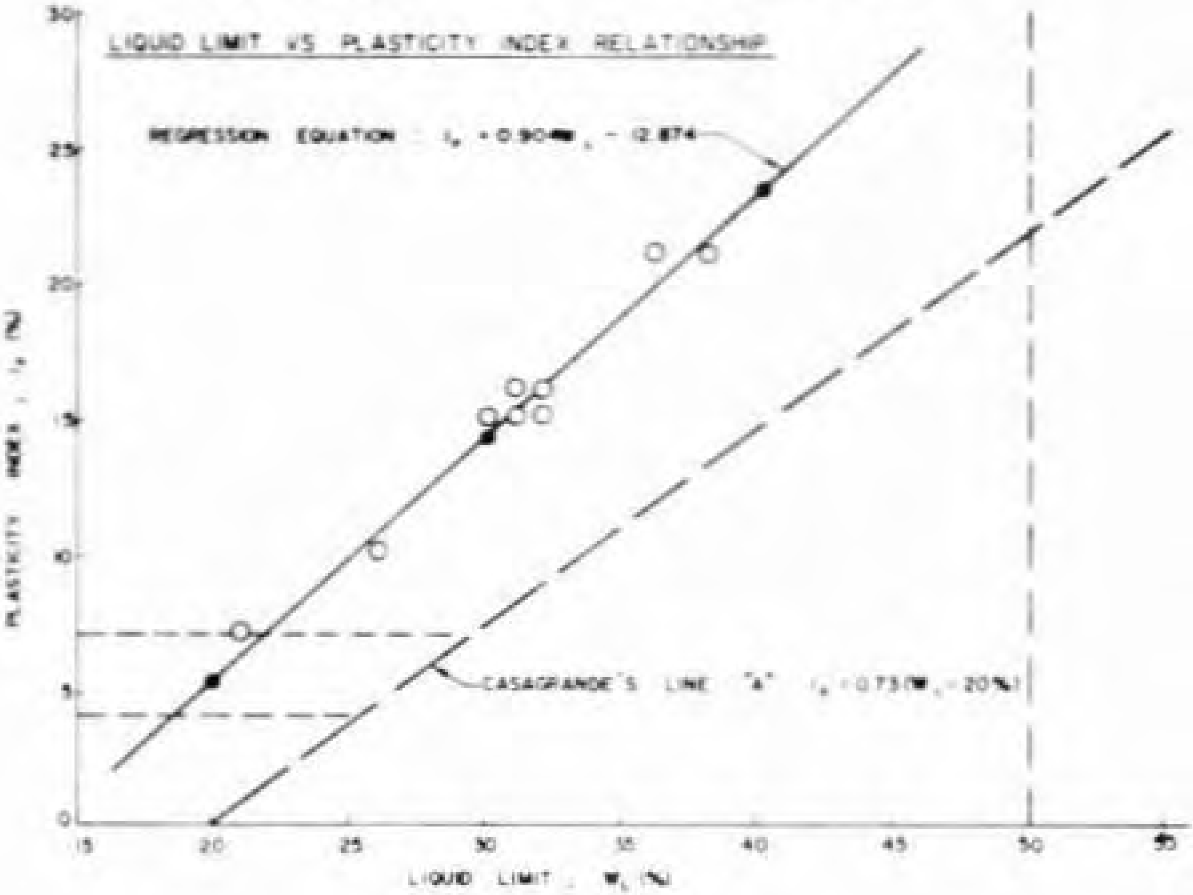
STRATUM : B

ORIGIN : LAKEBED

STATISTICAL SOIL CLASSIFICATION

TEXTURAL : SILTY CLAY

AASHO : A - 6(9)



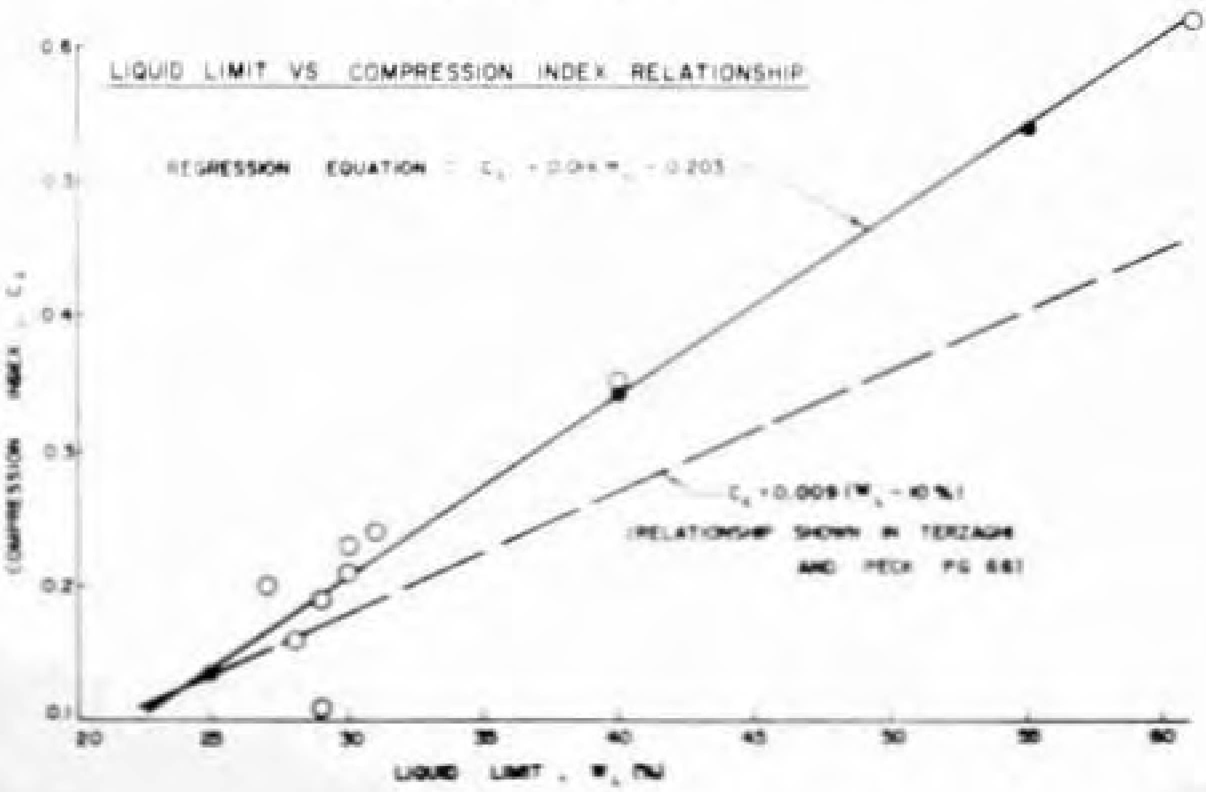


FIGURE 8

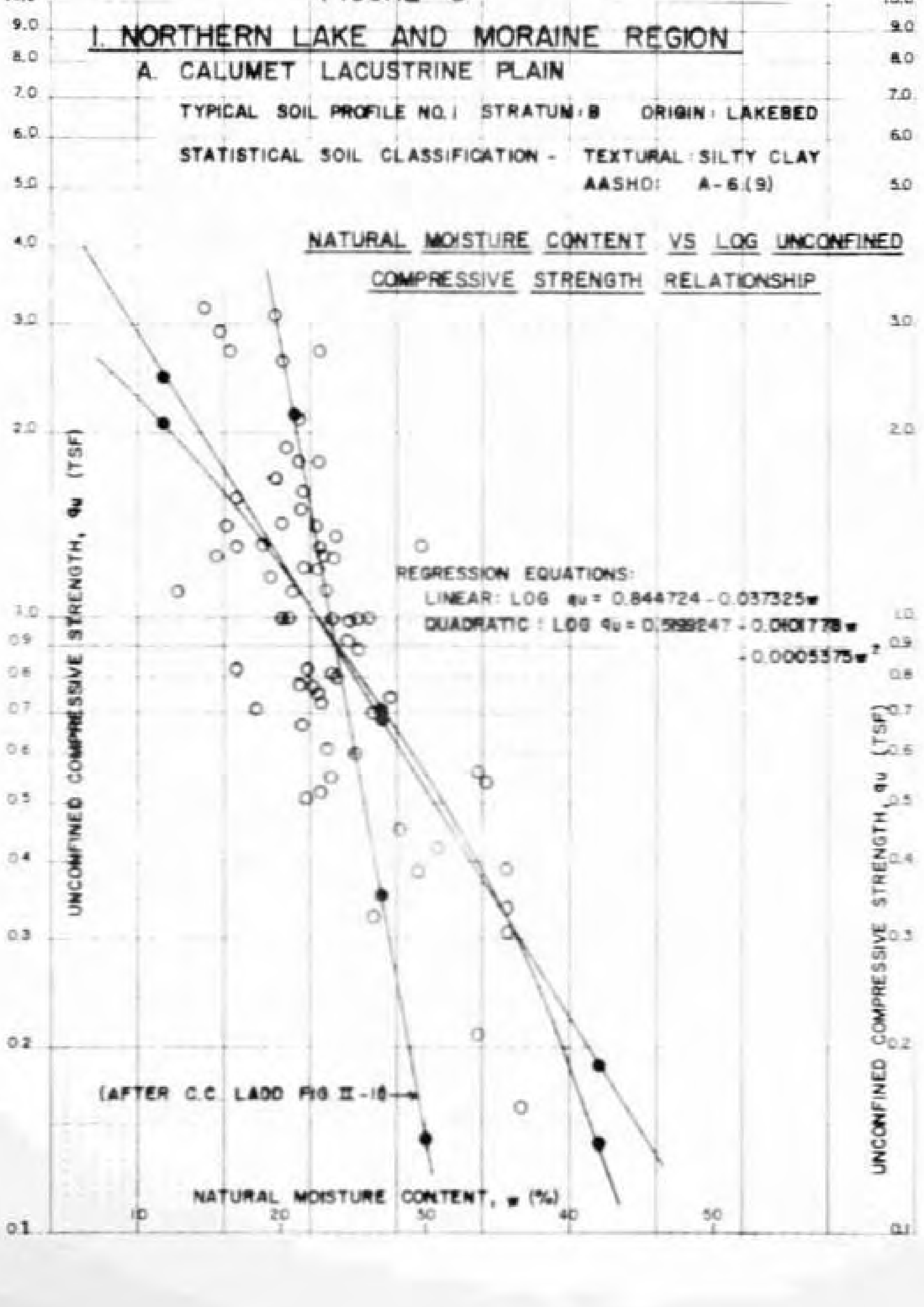

I. NORTHERN LAKE AND MORAINE REGION
A. CALUMET LACUSTRINE PLAIN
TYPICAL SOIL PROFILE NO. I STRATUM: B ORIGIN: LAKEBED
STATISTICAL SOIL CLASSIFICATION - TEXTURAL: SILTY CLAY
AASHO: A-6 (9)
NATURAL MOISTURE CONTENT VS LOG UNCONFINED COMPRESSIVE STRENGTH RELATIONSHIP
REGRESSION EQUATIONS:
LINEAR: LOG qu = 0.844724 - 0.037325w
QUADRATIC: LOG qu =
- 0.0005375w²
(AFTER C.C. LADD FIG II-18
UNCONFINED COMPRESSIVE STRENGTH, qu (TSF)
NATURAL MOISTURE CONTENT, w (%)
10
20
30
40
50
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

TABLE 4. RATINGS OF HIGHWAY SOILS CONSIDERATIONS FOR LANDFORMS WITHIN PHYSIOGRAPHIC REGIONS OF INDIANA
Northern Lake & Moraine Region
Calumet Lacustrine Plain

	HIGHWAY SOILS CONSIDERATIONS																																		
	Cut Design							Embank. Design						Embank. Foundations									Subgrades				Structure Design								
																											w/Foot.			with Piles					
	A. Soil Backslope Instability	B. Rock Backslope Instability	C. Ground Water Control	D. Erosion Potential	E. Surface Drainage	F. Sinkholes & Solution Channels	G. Natural Slope & River Bank Instability	A. Soil Sideslope Instability	B. Rock Sideslope Instability	C. Soil Type, Comp. Prop. & Placement Methods	D. Rock Type, Compaction & Placement Methods	E. Erosion Potential	F. Surface Drainage	A. Inadequate Shear Strength Potential	B. Excessive Settlement Potential	C. Ground Water Control	D. Organic Deposit Occurrences	E. Localized Areas of Unstable Soils	F. Liquefaction Potential	G. Sinkholes & Solution Channels	H. Surface Drainage	I. Design & Number of Culverts & Conduits	A. Support Characteristics	B. Frost Action Potential	C. Pumping Potential	D. Spring & Swell Potential	A. Instability Potential	B. Excessive Settlement Potential	C. Scour Potential	D. Instability Potential	E. Excessive Settlement Potential	F. Negative Skin Friction Potential	G. Predetermination of Pile Lengths	H. Scour Potential	I. Determin. of Lat. Earth Press. for Ret. Struct.
Dunes (Wisconsin) (Sand)	L		L	H	H		L	L		L		H	H	L	L	L	L	L	L		L	L	H	L	L	L	L	L	H	L	L	L	L	H	L
Lacustrine (Wisconsin) Surf./Bur. (Clay & Silty Clay)	M		L	M	M		M	L		M		M	M	M/L	M/H	L	L	M			H	M/H	L	M	H	H	M	M/H	M/H	L	M/H	M/H	M/H	M	H
Depressions & Stream Channels (Recent-Wisconsin) (Peat & Muck-Marl)	H		L	H	H		H	H		H		H	H	H	H	L	H	H			H	H	L	L	H	H	H	H	H	M	M	H	H	H	H
Ground Moraine (Wisconsin) (Clay & Silty Clay)	L		L	M	M		M	L		L		M	M	M	M	L	L	M			M	M	M	M	H	H	M	M	M	L	L	M	M	M	M

Note: L(Low), M(Medium), H(High)-Indicates there is little, average, high likelihood of major (deserving detailed consideration) problems developing, respectively.

planning, route location and design. One must always keep in mind that: (a) these ratings are generalizations within a landform, and (b) they reflect the present standards, policies and procedures used by the Indiana State Highway Commission for the design and construction of modern highway facilities. It is emphasized that detailed information is needed at a specific location before final decisions are made. The information in this study may influence a detailed investigation, but does not replace it. Only if a partial study of a project were to reveal conditions extremely similar to those developed within this investigation, and if there were sufficient data available in this study to lead to statistically sound conclusions, may a complete detailed study be judged unwarranted for that particular project. This decision should always be made by a competent, experienced soils engineer.

CONCLUSIONS AND RECOMMENDATIONS

1. The Physiographic Subdivision Approach outlined in this study can lead to meaningful and worthwhile implications and conclusions for use in the preliminary stages of planning, route location and design of modern highway facilities in the State of Indiana.

2. To increase the usefulness of this approach, a further subdivision of the physiographic units (shown on Figure 1) is recommended. The landforms or Engineering Soil Parent Material Areas shown in (3), seem to define areas within which one can indeed generalize as to the class and severity of highway soil problems with which he must cope.

3. The significant factors influencing a regional approach to highway soils considerations are the geologic origin and complexity of

parent materials (landforms), topography, and the general texture of the parent materials (particularly the magnitude of the clay fraction).

4. Methods and procedures presented in the "Generalized Quantification of Significant Factors Influencing a Regional Approach", page 10, provide a useful means for generally quantifying the factors of geologic origin and complexity of parent materials (landforms), and topography. Data developed in this phase of the study, and related to the frequency of occurrence of landforms, are the basis for what has been defined as the first dimension or degree for the Measure of Uniformity within physiographic regions.

5. The methods and procedures presented in the "Specific Quantification of Significant Factors Influencing a Regional Approach", page 19, provide a useful means for specifically quantifying the three significant factors of Item 3. Data developed in this phase of the study, and related to the frequency of occurrence of soil types within landforms, are the basis for what has been defined as the second dimension or degree for the Measure of Uniformity within physiographic regions. The typical profiles and regression equations for pertinent relationships, which were developed for landforms within the Calumet Lacustrine Plain physiographic region, could comprise a very valuable cataloging of soils experiences. If these relationships were developed for the significant landforms within each physiographic region, they could lead to greater economy in the performance of soil and foundation investigations, or at least a redistribution or concentration of any efforts to the known so-called problem landforms.

6. Presented in Table 4 are the "Ratings of Highway Soils Considerations for Landforms within Physiographic Regions in Indiana", for the Calumet Lacustrine Plain. The writers consider this information as having the greatest potential value for soils engineers inexperienced in this geographical location. The principal usefulness of these ratings is in preliminary studies related to highway planning, route location and design. This usefulness would be expanded several fold by the constructive criticism of other experienced soils engineers in this locality.

Any statements and conclusions made in this study represent the personal views of the writers based on their experience, and they should not be interpreted necessarily to represent the views of other personnel of the Indiana State Highway Commission.

ACKNOWLEDGMENTS

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